DCS-SYR-88-80

AD-A203 419

WAVEFORM DATA COLLECTION FOR SOURCE INVERSION STUDIES

ANNUAL REPORT (JUNE 1987-JUNE 1988)

02 AUGUST 1988

Prepared by:

William N. Alexander
Raymond H. Kimmel
Lauren Malaspina

Sponsored by:

Defense Advanced Research Projects Agency (DoD)
DARPA/PM, Arlington, VA 22207
ARPA Order No. 4511, Amd. 13

Issued by:

Air Force Technical Applications Center
Under Contract F08606-87-C-0017 (PA DT/7160)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS: None
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for Public Release - Distribution is unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): DCS-SYR-88-80	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: ENSCO, Inc. / 6b. OFFICE SYMBOL (If applicable): DCS	7a. NAME OF MONITORING ORGANIZATION: Air Force Technical Applications Center
6c. ADDRESS (City, State and ZIP Code): 445 Pineda Court, Melbourne, Florida 32940	7b. ADDRESS (City, State and ZIP Code): Patrick Air Force Base, Florida 32925
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Defense Advanced Research Project Agency (DoD) / 8b. OFFICE SYMBOL (If applicable): PM	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: F08606-87-C-0017
8c. ADDRESS (City, State and ZIP Code): Arlington, Virginia 22207	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
	DT/7160		

11. TITLE (Include Security Classification): Waveform Data Collection for Source Inversion/ Studies

12. PERSONAL AUTHOR(S): Alexander, William N.; Kimmel, Raymond H.; Malaspina, Lauren

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Annual	FROM 15 Jun 87 TO 14 Jun 88	88 Aug 02	18

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB. GR.

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Digital Seismic Data Base; Hand-Digitized Seismic Data

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report covers seismic waveform collection activities under Contract F08606-87-C-0017 for the period 15 June 1987 through 14 June 1988.

The primary purpose of this contract is to provide a data base of digital long period seismograms from selected large underground explosions, to be used in source inversion research. An added task requires the collection of digital Lg phases to be used in magnitude studies.

Digital seismograms in this data base are collected by hand-digitizing analog seismograms from stations in the World Wide Standard Seismograph Network (WWSSN) and by collecting existing digital data from stations in the Atomic Energy Detection System (AEDS). A number of waveforms have also been hand-digitized from AEDS analog recordings.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
MSgt. Martin C. Monson	(407) 494-2751	AFTAC/TTES

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

Table of Contents

List of Tables

1.0 INTRODUCTION

This report describes the seismic waveform collection activities under Contract F08606-87-C-0017 for the one year period from 15 June 1987 through 14 June 1988. Data selection, sources, methodology and characteristics are discussed herein.

Basic contract tasking requires the collection of long-period WWSSN, SRO (or GDSN) and AEDS waveform data for a prioritized set of 26 large underground explosions. These explosions include 15 from the Soviet Novaya Zemlya site, three from the U.S. Amchitka Island tests and six from the French test site on Mururoa Atoll. The events are listed in priority order in Table 1. All data collection work has been completed for the basic tasking although documentation continues.

Additional tasking under this contract requires collection of short period vertical seismograms covering the Lg phase arrivals for a large number of US and Soviet underground explosions. This work was begun in April 1988 and is approximately 20% complete.

Indices (matrices) for all data collected will be prepared prior to project conclusion.

2.0 EVENTS AND STATION NETWORKS

The events specified for long period data collection are shown in priority order in Table 1. For Lg collection, all US events will be used which are $\leqq$ 300 kt and detonated below the water table. In addition, five US PNE events and 92 large Shagan River explosions have been identified.

All AEDS and WWSSN stations within ~20° to ~100° of each test site, were considered for long period data collection. WWSSN stations specified for consideration in Lg data collection from the Nevada Test Site (NTS) and the Soviet Shagan River (SR) site, are shown in Table 2. Stations for Lg data collection from other test sites have not yet been specified.

TABLE 1. Prioritized Events Specified for Long Period Waveform Collection.

PRIORITY	DATE	TEST SITE
1	28 AUG 72	NOVAYA ZEMLYA
2	12 SEP 73	NOVAYA ZEMLYA
3	27 SEP 71	NOVAYA ZEMLYA
4	14 OCT 70	NOVAYA ZEMLYA
5	21 OCT 75	NOVAYA ZEMLYA
6	27 OCT 66	NOVAYA ZEMLYA
7	14 OCT 69	NOVAYA ZEMLYA
8	27 OCT 73	NOVAYA ZEMLYA
9	02 NOV 74	NOVAYA ZEMLYA
10	29 AUG 74	NOVAYA ZEMLYA
11	23 AUG 75	NOVAYA ZEMLYA
12	07 NOV 68	NOVAYA ZEMLYA
13	21 OCT 67	NOVAYA ZEMLYA
14	10 AUG 78	NOVAYA ZEMLYA
15	24 SEP 79	NOVAYA ZEMLYA
16	18 OCT 75	NOVAYA ZEMLYA
17	29 SEP 76	NOVAYA ZEMLYA
18	27 SEP 73	NOVAYA ZEMLYA
19	06 NOV 71	AMCHITKA ISLAND
20	02 OCT 69	AMCHITKA ISLAND
21	29 OCT 65	AMCHITKA ISLAND
22	25 JUL 79	MURUROA ATOLL
23	30 NOV 78	MURUROA ATOLL
24	19 MAR 77	MURUROA ATOLL
25	24 NOV 77	MURUROA ATOLL
26	25 MAY 83	MURUROA ATOLL

TABLE 2. Station Networks for Lg Collection.

NTS	SR
AAM	KEV
ALQ	KOD
ATL	KON
BKS	LAH
BLA	KBL
MSO	MSH
COR	NDI
DAL	NUR
DUG	POO
FLO	QUE
FVM	SHI
GEO	SHL
GOL	TAB
LON	UME
LUB	
OGD	
GSC	
RCD	
SCP	
SHA	
TUC	
WES	

3.0 DATA SELECTION

For source inversion studies both vertical and horizontal long period waveform data were collected. If vertical data could not be collected, an attempt was made to collect data from both horizontal components. Where only one horizontal component was available, no data collection was attempted. Waveforms collected from the priority event set under prior contracts, were not re-digitized under this effort. Only positive arrivals with signal-to-noise ratios of about 2:1 or better were hand-digitized. All other signal arrivals were collected if the recording quality allowed and (for hand-digitized data) if turning points were visible or could be easily extrapolated.

Table 3 shows the number of waveforms collected for each event.

4.0 WAVEFORM CHARACTERISTICS

4.1 Hand Digitized Long Period Data.

Where sufficient usable analog data permitted, a minimum of 33.33 minutes were digitized for each component. All components for each station/event combination were begun at the same time. All waveforms were started on minute marks chosen to allow approximately three minutes of background prior to signal onset (P, S, Love, or Rayleigh). In some cases where Rayleigh and Love waves were the only visible arrivals, these trains are approximately centered in the 33.33 minute window.

In accordance with Project Office instructions, priority was given to surface wave collections. P phases were only digitized when well-recorded (S/N ratio of $\geq$ 2:1) and when accompanied by usable surface groups. In most cases where P was digitized as the first arrival, data were digitized continuously through Rayleigh. A few waveforms, however, have time gaps between P and Rayleigh segments, ranging from approximately three to eight minutes. These intentional omissions serve to reduce the amount of (essentially) background data digitized between P and surface group arrivals at distances from about 75° to 100°.

TABLE 3. Long Period Collection Summary.

EVENT	SITE	WAVEFORMS COLLECTED		
		WWSSN	AEDS	TOTAL
1. 29 OCT 65	AMCHITKA IS.	14	20	34
2. 27 OCT 66	NOVAYA ZEMYLA	106	7	113
3. 21 OCT 67	NOVAYA ZEMLYA	--	7	7
4. 07 NOV 68	NOVAYA ZEMLYA	46	11	57
5. 02 OCT 69	AMCHITKA IS.	92	37	129
6. 14 OCT 69	NOVAYA ZEMLYA	71	31	102
7. 14 OCT 70	NOVAYA ZEMLYA	72	36	108
8. 27 SEP 71	NOVAYA ZEMLYA	128	28	156
9. 06 NOV 71	AMCHITKA IS.	239	1	240
10. 28 AUG 72	NOVAYA ZEMLYA	153	23	176
11. 12 SEP 73	NOVAYA ZEMLYA	149	5	154
12. 27 SEP 73	NOVAYA ZEMLYA	4	5	9
13. 27 OCT 73	NOVAYA ZEMLYA	--	6	6
14. 29 AUG 74	NOVAYA ZEMLYA	--	5	5
15. 02 NOV 74	NOVAYA ZEMLYA	--	9	9
16. 23 AUG 75	NOVAYA ZEMLYA	12	10	22
17. 18 OCT 75	NOVAYA ZEMLYA	1	44	45
18. 21 OCT 75	NOVAYA ZEMLYA	97	4	101
19. 29 SEP 76	NOVAYA ZEMLYA	--	17	17
20. 19 MAR 77	MURUROA	--	14	14
21. 24 NOV 77	MURUROA	--	89	89
22. 10 AUG 78	NOVAYA ZEMLYA	--	--	0
23. 30 NOV 78	MURUROA	--	--	0
24. 25 JUL 79	MURUROA	--	--	0
25. 24 SEP 79	NOVAYA ZEMLYA	23	--	23
26. 25 MAY 83	MURUROA	--	--	--
TOTALS:		1207	409	1616

4.2 Calibrated Digital Long Period Data.

Digital AEDS data were retrieved and calibrated by a comparison with analog records for three events. A total of 115 long period waveforms (2000 data points each) resulted from this effort. No additional digital data from SRO or GDSN sources were found for the selected events.

4.3 Hand-Digitized Lg Data.

Direct Lg arrivals are being hand-digitized within a 3.6 to 3.2 km/sec window. Digitizing begins about ten seconds prior to the 3.6 km/sec arrival and continues for at least 1000 data points (50 seconds). Additional 1000 point segments are digitized as necessary, to complete the window.

In addition to direct arrivals, Lg coda segments are being digitized for selected events. Coda waveforms begin at the end of direct Lg waveforms and continue for as many 1000 point segments as are required. Coda segments are not necessarily contiguous with direct arrival segments.

5.0 DELIVERED DATA

5.1 Long Period Data.

All long-period waveforms collected in this effort were merged with long period waveforms collected under prior contracts (for the 26 event set). AEDS and WWSSN data were delivered on separate magnetic tapes. Additionally, the small amount of classified AEDS data was delivered separate from the unclassified AEDS data.

5.2 Lg Data.

While no Lg data deliveries have yet been made, we anticipate each delivery of direct arrival Lg waveforms to encompass about 25 events. Waveforms describing Lg coda for selected events, will be delivered on separate magnetic tapes.

6.0 DIGITIZING SYSTEM DESCRIPTION

A Minolta Model RP407 microfilm reader/printer was used to produce enlarged paper prints of desired signals from original station film or from duplicates of station film in microfiche or 70 mm film chip format. Signals on these paper prints were digitized using a TALOS series, Model 640 CYBERGRAPH system which consists of a 30x40 inch tablet, a 16 button hand-held cursor and TALOS Smart firmware. Waveform header information is entered interactively using an HP2382A terminal. These data and the TALOS output are collected, formatted and stored by the ENSCO HP-1000 computer. Overlay plots, to verify digitizing accuracy, are made for each signal using an HP7225B plotter.

The system operation has been thoroughly described by Kraft et al. (1982). Only minor changes were made to the software to improve efficiency of operation. Using this system, short period digital waveforms containing frequencies of three Hertz were routinely reproduced with a high degree of accuracy. Where recording quality and trace width were optimal, frequencies of five Hertz were easily obtained. Long period frequency resolution is limited by the sampling standard (1 sample/sec) to about 0.25 Hz.

7.0 DATA QUALITY AND RELIABILITY

Data collected during this project is generally of excellent quality. Certain assumptions are necessarily made in collection procedures, however, and some errors may remain.

In the calibration of digital data and in assigning parameters to hand-digitized data, information given on microfiche headers (station film box labels) or on station film wrapper is assumed to be accurate. Analog recordings are used as a standard for channel identification, magnification, timing, polarity and calibration driving force information. Signal polarity is reversed if it is apparent that the analog and digital waveforms are of opposite polarity.

Station time corrections are applied to pertinent waveforms to within ± 0.1 seconds for short period and ± 1.0 second for long period data. The distortion

effects of spiral recording (α) are removed or considerably lessened for all WWSSN waveforms. Because of the difficulty in determining the exact correction needed, some waveforms retain a noticeable "tilt" from the vertical.

Data reviewed for collection is rejected when obviously defective, when operating parameters cannot be ascertained and when instrumentation problems are known. However, numerous waveforms have been collected which were degraded to some extent by cultural, natural or system noise. The amount of degradation allowable before rejection is not rigidly defined and is usually determined by the individual analyst. In general, if it is felt that signal degradation prevents accurate reproduction or calibration, or cannot easily be overcome by processing techniques, the data are rejected.

8.0 DATA FORMAT

All data collected under this project are being written in TGS Archive format on nine-track 1600 BPI or 6250 bpi tapes by an IBM 4381 with the following tape format:

a. blocksize (BLKSIZE) = 2116 bytes,
b. logical record length (LRECL) = 2122 bytes,
c. record format (RECFM) = variable length records (VS),
d. data representation = EBCDIC and binary.

The actual data on the tape are written as INTEGER*2 halfwords. There are 1050 halfwords per record with the first 50 halfwords allocated for header information and the remaining 1000 halfwords allocated for waveform data. Prior to the 1050 halfwords in the record, there are two INTEGER*4 fields allocated for a record number and record length.

The waveform data are in units of millimicrons (mμ) of ground motion after multiplication of each data point by the scale factor extracted from the eighth

halfword. The following Fortran code will provide the data in millimicrons for both long period and short period records in the floating point array FDATA:

```
      INTEGER*4NREC, LREC
      INTEGER*2HEADER(50),IDATA(1000)
      REAL*4FDATA(1000)
      ●
      ●
      ●
      ●
      READ(8)NREC,LREC,HEADER,IDATA
      LEN = HEADER(3)
      SCALE = HEADER(8)/100
      DO1001 = 1,LEN
100 FDATA(I) = IDATA(I)*SCALE
      ●
      ●
      ●
      STOP
      END
```

The original TGS archive format, which allows for only a two character station ID in the header, lacks sufficient flexibility to allow other network data such as WWSSN, Canadian and GDSN to be included with the AEDS under the TGS Archive format. In 1983, with Project Office concurrence, a new standard was initiated to allow for variable length station ID's within the context of a new TGS Archive format. This latter format has been designed to be compatible with the Tape Conversion System, TAPCONS, now in use at AFTAC.

Essentially, the character content of header halfwords 15 through 18 (HEADER(15-18) remains the same for AEDS data. Binary zeros are placed in HEADER(20-24) and a character event ID is placed in HEADER(25-30). If a station ID is to contain three to five characters, these are placed in the header starting in HEADER(15). The sixth character in the station-channel field must then be left blank to note continuation of channel information in HEADER(18) and repeated in HEADER(21). The first byte of HEADER(22) contains a single character response designator to satisfy a multitude of AFTAC programs which allow for only a single character response designator. This AFTAC response has been assigned the following values for GDSN/WWSSN/DWWSSN stations:

AFTAC Response	Chiburis Response and Period		
	RESP	PER	NET
A	1	SP	WWSSN
B	2	LP	WWSSN
C	3	LP	WWSSN
D	4	LP	WWSSN
E	5	LP	WWSSN
F	6	LP	WWSSN
J	7	LP	WWSSN
G	8	SP	SRO
G	9	LP	SRO
H	0	SP	DWWSSN
H	0	LP	DWWSSN

The original Chiburis response is preserved by placing its value in HEADER(24) in binary. Any channel information is placed in the second byte of HEADER(22) and the two bytes of HEADER(23). If a waveform is hand-digitized, an "H" is placed in the first byte of the channel field (second byte of HEADER (17) for AEDS and in the second byte of HEADER (22) for WWSSN, Canadian and GDSN). This "H" replaces "I" in AEDS channel designators.

Figure 1 illustrates past and present TGS Archive formats. The TAPCONS compatible version is the new standard TGS Archive format, and is used for all digital data delivered under this project. Additional header information is shown in Table 4.

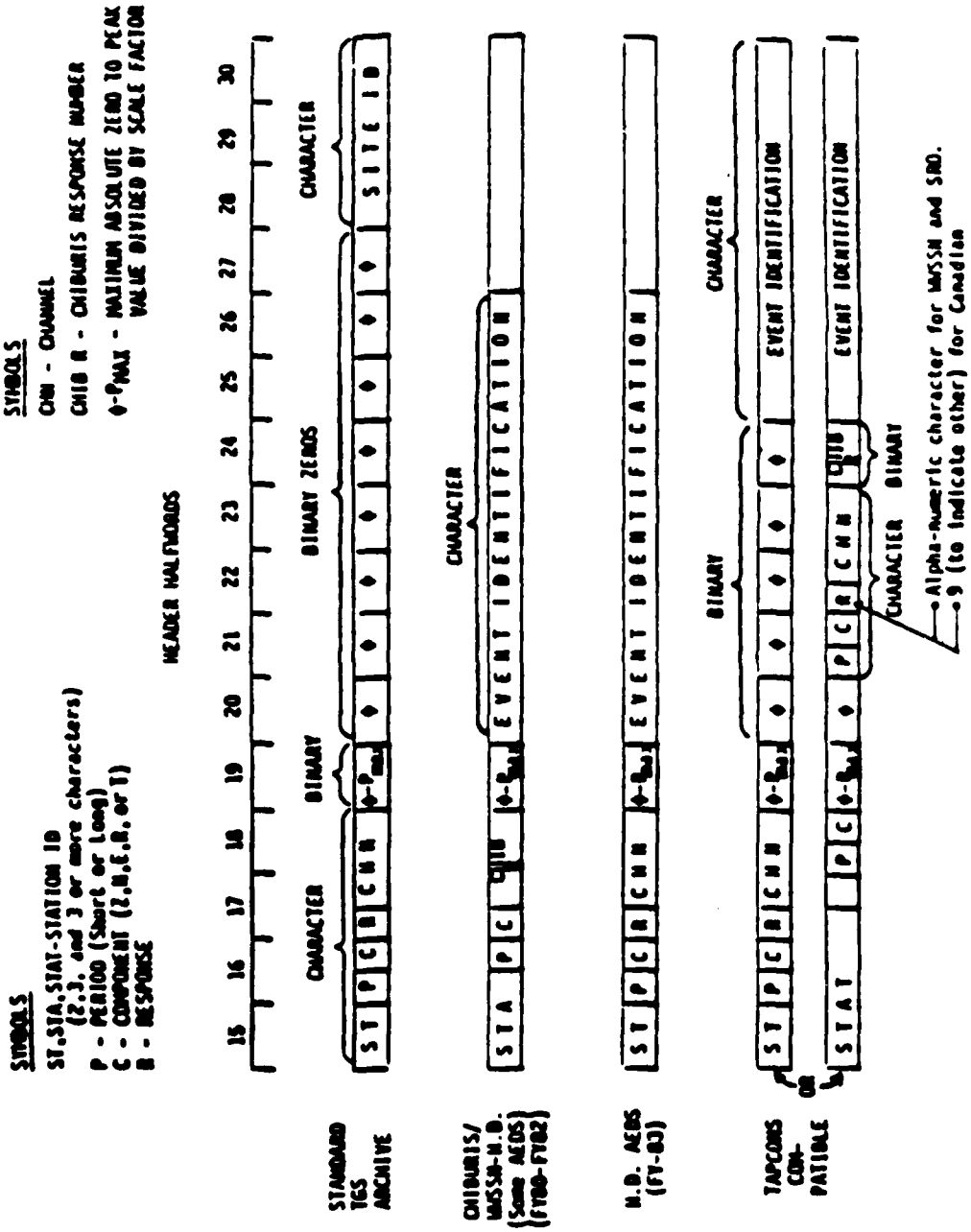

FIGURE 1. Variations of TGS Archive Format.

Table 4. Header Information

HALFWORD	
1	Digital rate times 100 (integer); e.g., 2000 = 20 samples per second.
2	One
3	Waveform length in halfwords (integer); e.g., 846.
4	Start time (hours x 100 + minutes).
5	Start time (seconds x 10).
6	2005.
7	Blank.
8	Scale factor x 100.
9-14	Year, day of year, hour, minute, second, and tenths of a second for start of data (EBCDIC); e.g., 763611416396, where year = 76, DOY = 361, hour = 14, min = 16, sec = 39.6.
15-18	Station code, period, component, AFTAC response number, and channel; eg., IMSZ1101 for AEDS network.
19	Maximum absolute zero-to-peak value of data divided by scale factor (integer) i.e., Max O-P value in mμ HEADER (19) x HEADER(8)/100.
21-23	Binary zeros for AEDS network. Period, component, AFTAC response, and channel for non-AEDS (EBCDIC).
24	Binary zero for AEDS. Chiburis response number (binary) for non-AEDS.
25-30	Event ID (EBCDIC).
31-50	Not used by ENSCO.

9.0 REFERENCES

Kraft, G.D., W.N. Alexander, S.J. Price, G.W. Pound, T.J. Corbin and R.C. Kemerait, "Extension of Digital Data Base of World-Wide and Canadian Seismograms for Selected Underground Explosions II," ENSCO, Inc., Report DCS-STR-82-62, 1982.